OPTICAL MULTIPLE TRANSMISSION METHOD, OPTICAL NETWORK AND OPTICAL TRANSMISSION APPARATUS

BACKGROUND OF THE INVENTION

5   The present invention relates to a wavelength multiplexing transmission method and an optical network in which a plurality of optical signals of different wavelengths are multiplexed and transmitted, and an optical transmission apparatus which can be used for the transmission method and the optical network.

10   Heretofore, a method as stated below has been known as an expedient for extending a ring network based on wavelength multiplexing technology.   It is contained in, for example, Rajiv Ramanswasmi and Kumar N. Sivarajan: "Optical Networks -A Practical Perspective-" published by Morgan Kaufmann Publishers,

15   page 449. A general construction for the method has been as shown in, for example, Fig. 10. 15 in the book. The method is founded on the construction that, in case of realizing a ring network of the type which drops or adds only specific wavelengths, optical signals of wavelengths propagating via a certain node apparatus are outputted at

20   the same wavelengths as the inputted wavelengths.   Accordingly, a practicable node apparatus is constructed including a dropping section

in which any signals are derived from a wavelength demultiplexing

unit located on the input side of the node apparatus and are outputted

outside, and an adding section in which optical signals given from

outside are connected to a wavelength multiplexing unit located on the

5   output side of the node apparatus. Herein, the certain wavelength

signals delivered from the wavelength demultiplexing unit are directly

delivered to the wavelength multiplexing unit as the signals having the

same wavelengths. Thus, the optical signals which are dropped or

added by the apparatus itself are externally outputted or inputted via

10   the dropping section or the adding section. On this occasion, the

apparatus does not drop or add any wavelengths for itself, but it

transmits the optical signals inputted for other apparatuses, from one

side to the other side thereof without changing the wavelengths of the

optical signals. Although the network of ring scheme (ring network) is

15   exemplified here, a similar method is known also in a linear network.

The "linear network" is a network architecture wherein node

apparatuses are arrayed in one row, and wherein optical signals of any

wavelengths are dropped or added by the node apparatuses arranged

midway.

20   Next, a node apparatus for such a network will be concretely

exemplified. Fig. 1 shows an example of the node apparatus which has

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a wavelength multiplexing function and which incarnates the dropping and adding of specific wavelengths. A wavelength dropping section includes a first space switching unit 1, a wavelength demultiplexing unit 3 and an interface unit 5 for input wavelength-

5 multiplexed optical signal 7. The wavelength demultiplexing unit 3 demultiplexes the input wavelength-multiplexed optical signal 7 into individual wavelengths ($\lambda 1$, $\lambda 2$, $\lambda 3$, ---, λN), which are respectively delivered to predetermined transmission lines 9. The first space switching unit 1 drops optical signal of desired specific wavelengths in

10 the input wavelength-multiplexed optical signal 7. The interface unit 5 outputs the dropped input lights as desired dropped optical signals. Thus, the wavelength dropping section demultiplexes the input wavelength-multiplexed optical signal 7 into the individual wavelengths and drops the desired wavelengths so as to output the

15 dropped optical signals 12.

On the other hand, a wavelength adding section includes an interface unit 6, a second space switching unit 2 and a wavelength multiplexing unit 4 for output wavelength-multiplexed optical signal 8. The interface unit 6 outputs optical signals to-be-added 13. Optical

20 signals 10 transmitted from the first space switching unit 1, and the optical signals to be-added 13 transmitted from the interface unit 6 are

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delivered to predetermined transmission lines 11 via the second space

switching unit 2 in accordance with connection route settings for the

optical signals respectively having the individual wavelengths. The

optical signals 11 of the plurality of wavelengths ($\lambda 1$, $\lambda 2$, $\lambda 3$, ..., λN) thus

5   delivered are wavelength-multiplexed by the output wavelength

multiplexing unit 4, and the resulting optical signal is outputted as the

wavelength-multiplexed optical signal 8. Here, each of the first space

switching unit 1 and the second space-switching unit 2 is constructed

of optical switches etc.

10   Apart from the above expedient in which the dropping or

adding section is constructed of the optical switches, a wavelength

multiplexer of drop/add type employing "Fiber Bragg Grating"

technology has also been proposed. The drop/add type wavelength

multiplexer is illustrated in, for example, Fig. 3. 60 on page 172 of the

15   aforementioned book "Optical Networks -A Practical Perspective-".

The fiber Bragg grating technology is optical filter technology which

utilizes periodical refractive index modulation within an optical fiber

as is formed when the optical fiber doped with Ge (germanium) is

irradiated with the interference fringes of ultraviolet light. The

20   construction of the drop/add type wavelength multiplexer employing

the fiber Bragg grating technology is shown in Fig. 2. A light dropping

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section 20 includes a circulator 26 and a splitter 27. In the circulator 26,

light propagating rightwards from left is totally transmitted, whereas

light propagating leftwards from right is totally reflected downward to

the splitter 27 as viewed in the figure. In fiber Bragg gratings 24, only

5   lights of wavelengths $\lambda 1$, $\lambda 2$, $\lambda 3$ and $\lambda 4$ in the rightward light are

totally reflected leftwards. A light adding section 22 includes a

combiner 28 and a coupler 29. In the figure, numeral 7 indicates the

input wavelength-multiplexed optical signal, and numeral 8 indicates

the output wavelength-multiplexed optical signal.

10   With the fiber Bragg grating technology, the optical signals of

the specific wavelengths are derived by a diffraction grating at an

input stage in a state where the wavelengths are multiplexed as they

are.

It is common to both the dropping/adding methods stated

15   above that the wavelengths of optical signals which are transmitted

remain unchanged.

A network wherein a plurality of node apparatuses of the type

dropping and adding optical signals of specific wavelengths are

connected, has a difficulty as explained below.

20   In the network wherein the plurality of apparatuses dropping

and adding the optical signals of specific wavelengths are connected in

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a ring scheme or a linear scheme, a request for connecting an optical

channel is generally made by designating any two of the plurality of

apparatuses which constitute the whole network. In that case,

regarding which of wavelengths is to be used for the connection, a

5   wavelength not used in any zone is selected in accordance with the

situation of uses of the wavelengths in all zones. Various algorithms

corresponding to the individual aspects of uses have been proposed for

the selection. Typical examples of the algorithms are as follows: The

first example is a method wherein fixed Nos. denoted by natural

10   numbers are assigned to wavelengths usually applied, and wherein an

unused wavelength is selected from the smaller one of the Nos. The

second example is a method wherein any wavelength is selected from

among unused wavelengths by employing a random number.

In an actual transmission circuit, however, a problem is posed

15   as stated below. In general, requests for channels to be connected are

not fully determined at the time of the construction of the network.

Accordingly, the optical channels of the transmission circuit are added

or deleted in accordance with the requests for channels arising every

day, and the settings of the channels need to be altered in

20   correspondence with the addition or deletion of the optical channels.

With the prior-art technique mentioned above, it is required to

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select the wavelength which is not used in any of all the zones of the channel. Accordingly, when a request for connection has occurred in a certain channel, a wavelength which is not used in any of the zones included from a certain apparatus to another apparatus must be

5   selected.   In the nonexistence of such a wavelength, the optical transmission channel requested to be connected cannot be connected in spite of the existence of unused wavelengths in the individual zones.

This state is shown in Fig. 3. The figure exemplifies an optical network in the case where node apparatuses A - E, i.e. five apparatuses

10   100, 101, 102, 103 and 104 are connected in one row. Letters $\underline{a}$, $\underline{b}$, $\underline{c}$, ... and $\underline{h}$ indicate channels which are respectively connected to the node apparatuses. The respectively adjacent apparatuses are connected by a multiplex channel of four wavelengths. That is, the multiplex channel can accommodate, up to, four optical channels. Incidentally, the case

15   of the four wavelengths is mentioned here, but in general, the number of wavelengths is not especially restricted. Besides, although the node apparatuses are connected in one row in the example of Fig. 3, the same holds true even when node apparatuses are connected in a ring shape or in a mesh shape. Further, the algorithm of minimum value

20   selection as is the simplest algorithm shall be adopted here. Also, a request for a channel shall be an additional request in the ensuing

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description.

It is now assumed that requests for connections have occurred in the order of the channels a, b, c, d, ... and g. Then, the wavelengths of the smallest Nos. usable in compliance with the requests for the

5 connections of the channels are selected on the basis of the algorithm of the minimum value selection. Thus, the seven channels from the channel a to the channel g are set as shown in Fig. 3. By way of example, the channel a connects the node apparatuses A and B, and the wavelength of wavelength No. 1 is used for the channel. The

10 connections of the other channels are similarly understood. Here, it must be attended to that, in the case of the method which uses the same wavelengths in all the channels connected, each of the node apparatuses outputs the same wavelengths as the inputted wavelengths.

15 It is now considered that the request for the connection of the channel h has been further added. The channel h corresponds to the request for the connection from the node apparatus B to the node apparatus E. When the situation of uses of the wavelengths in the node apparatus C is viewed here, wavelength Nos. 3 and 4 are already

20 used on the left side (on the side of the node apparatus B), and wavelength Nos. 1 and 2 are already used on the right side (on the side

of the node apparatus E). Consequently, any wavelength usable on both the right and left sides in common does not exist in the node apparatus C. Accordingly, this example involves the problem that the channel h̲ cannot be added though the node apparatus although C has the unused wavelengths on both the right and left sides. For adding the channel h̲, therefore, it is necessary to build, for example, another network of ring scheme constituted by a plurality of similar apparatuses. This means that a wavelength multiplexing capability is not fully exploited in the multiplex system of wavelength multiplexing.

SUMMARY OF THE INVENTION

The main aspects of the present invention are as follows:

In accordance with a first aspect of the present invention, there is provided an optical multiplex transmission method comprising accepting an optical signal group in which optical signals of a plurality of wavelengths are multiplexed, from a first optical transmission line; converting the optical signal of the first wavelength included in the optical signal group, into the optical signal of the second wavelength different from said first wavelength; and multiplexing at least one of the optical signals of the wavelengths except said first wavelength, included in said optical signal group, and said optical signal of said

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second wavelength, and then outputting the resulting multiplexed optical signals to a second transmission line.

In accordance with a second aspect, there is provided an optical multiplex transmission method comprising accepting a first optical signal group in which optical signals of a plurality of wavelengths are multiplexed, from a first optical transmission line, and a second optical signal group in which optical signals of a plurality of wavelengths are multiplexed, from a second optical transmission line; converting the optical signal of the first wavelength included in the first optical signal group, into the optical signal of the second wavelength different from said first wavelength; multiplexing at least one of the optical signals included in said first optical signal group, at least one of the optical signals included in the second optical signal group, and said optical signal of said second wavelength, and then outputting the resulting multiplexed optical signals to a third optical signal line; and multiplexing at least one of the optical signals except the optical signals to be outputted to the third optical signal line, included in said first optical signal group, and at least one of the optical signals except said optical signals to be outputted to said third optical signal line, included in said second optical signal group, and then outputting the resulting multiplexed optical signals to a fourth

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optical signal line.

In accordance with a third aspect, there is provided an optical multiplex transmission method comprising allowing a first node apparatus to receive a wavelength-multiplexed optical signal group; to transmit at least one of optical signals included in the optical signal group, to a second node apparatus connected with the first node apparatus; to convert the optical signal of first wavelength included in said optical signal group, into the optical signal of second wavelength different from the first wavelength; and to transmit said optical signal of the second wavelength to a third node apparatus connected with said first node apparatus.

In accordance with a fourth aspect, there is provided an optical transmission apparatus comprising an input wavelength demultiplexing unit which demultiplexes a first optical signal group including optical signals of a plurality of wavelengths inputted from a first optical fiber, into the optical signals of the respective wavelengths; a wavelength multiplexing unit which multiplexes optical signals of a plurality of wavelengths, and which outputs the resulting multiplexed optical signals to a second optical fiber; a wavelength dropping unit which outputs predetermined optical signals among said optical signals of said respective wavelengths demultiplexed by said input

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wavelength demultiplexing unit; a wavelength adding unit which outputs predetermined optical signals in a second optical signal group including optical signals of a plurality of wavelengths externally inputted, to said wavelength multiplexing unit; and a wavelength

5   converting unit which converts the optical signal of first wavelength among said optical signals of said respective wavelengths demultiplexed by said input wavelength demultiplexing unit, into the optical signal of second wavelength different from the first wavelength, and which outputs said optical signal of the second

10 wavelength to said wavelength adding unit.

Further aspects of the present invention will become apparent from the ensuing description.

The essentials of the present invention will be summed up below. The difficulty in the optical transmission described above is

15 ascribable to the restriction of an apparatus construction that optical signals to be passed through each apparatus of any optical network must have identical wavelengths on the input side and output side of the apparatus. Here, if an optical signal of certain wavelength from the input side can be converted into an optical signal of different

20 wavelength within the apparatus so as to externally output the resulting optical signal, and if any unused wavelengths are

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respectively existent on the input side and the output side, the unused wavelengths will be permitted to pass through the apparatus irrespective of whether or not these wavelengths are in agreement.

This fact holds true also of optical signals which are connected via a plurality of zones. If the apparatuses can convert the wavelengths of the optical signals to be passed, and if unused wavelengths are respectively existent in the plurality of zones desired to be connected, it is permitted to set a corresponding optical channel, irrespective of the combination of the unused wavelengths. According to such a method, the maximum number of wavelengths can be utilized between the zones, and the capability of wavelength multiplexing can be exploited to the utmost.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an example of construction of a drop/add type wavelength multiplexer in the prior art;

Fig. 2 is a diagram showing an example of construction of a drop/add type wavelength multiplexer which employs fiber Bragg grating technology;

Fig. 3 is a diagram for explaining a prior-art method of setting wavelength routes in drop/add type wavelength multiplexing

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transmission;

Fig. 4 is a diagram for elucidating the principle of the present invention in the drop/add type wavelength multiplexing transmission;

Fig. 5 is a block diagram showing the construction of a

5   drop/add type wavelength multiplexer in an embodiment of the present invention;

Fig. 6 is a diagram showing an example in which a wavelength converting section in the embodiment is constructed of electric switches;

10   Fig. 7 is a diagram showing an example in which the wavelength converting section in the embodiment is constructed of optical switches;

Fig. 8 is a block diagram showing the construction of a drop/add type wavelength multiplexer in another embodiment of the

15   present invention;

Fig. 9 is a diagram showing a linear network in an embodiment of the present invention;

Fig. 10 is a diagram showing a ring network in an embodiment of the present invention;

20   Fig. 11 is a diagram showing a meshed network in an embodiment of the present invention; and

Fig. 12 is a flow chart for explaining examples of operations in the network in an embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE INVNENTION

5   The principle of the present invention will be elucidated with reference to Fig. 4. The figure is a conceptual diagram of an optical network for describing the basic idea of the present invention. Likewise to Fig. 3, Fig. 4 exemplifies the optical network in the case where node apparatuses A - E, i.e. five apparatuses 110, 111, 112, 113

10   and 114 are connected in one row. Letters a, b, c, ··· and h indicate channels which are respectively connected to the node apparatuses. Each node apparatus is exemplified as a multiplexer of four wavelengths, and it can accommodate, up to, four optical channels. Incidentally, the case of the four wavelengths of wavelengths Nos. 1

15   through 4 is mentioned here, but in general, the number of wavelengths is not especially restricted in the optical network to which the present invention is directed. Besides, although the node apparatuses are connected in one row in the example of Fig. 4, the present invention is similarly applicable to a different connection

20   scheme. The different connection scheme corresponds to, for example, a case where node apparatuses are connected in a ring shape or in a

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mesh shape.

The example as shown in Fig. 3 has the fundamental rule that the wavelengths propagating via the node apparatuses are the same. As explained before, under such a rule, there is the problem that any

5   channel cannot be increased in spite of the existence of unused wavelengths in individual zones.

In contrast, according to the present invention, the above difficulty is avoided in such a way that each node apparatus converts the wavelength of the inputted light so as to output the resulting

10 wavelength. Referring to Fig. 4, in a case where a request for connecting the channel h between the node apparatuses B and E has been received, the node apparatus C located midway executes the wavelength conversion. Owing to the wavelength conversion, the signal of wavelength No. 1 is converted into that of wavelength No. 3.

15 It is consequently permitted to set the channel h anew. The function of this wavelength conversion is indicated as "Wavelength conversion 1" in the figure. Besides, in a case where a request for connecting a channel i between the node apparatuses B and D has been further received here, the node apparatus C similarly executes the wavelength

20 conversion from wavelength No. 2 into wavelength No. 4. Thus, the channel i is set. The function of this wavelength conversion is

indicated as "Wavelength conversion 2" in the figure.

Now, practicable embodiments of the node apparatus itself according to the present invention will be described.

In general, the node apparatus is capable of two-way

5   transmissions. In each of the ensuing embodiments, however, only the construction of the transmission in one way will be shown for the brevity of illustration. In order to realize the two-way transmissions, the node apparatus may include besides the construction of each embodiment, the same construction so as to reverse a transmitting

10   direction. Further, two examples stated below are representative as a wavelength multiplexing method. The first is a one-way wavelength multiplexing system wherein wavelengths for one way are multiplexed in a single optical fiber. The second is a two-way wavelength multiplexing system wherein wavelengths for two ways are

15   multiplexed in a single optical fiber. In the present invention, how to construct the node apparatus is similar in both the wavelength multiplexing systems.

In general, the wavelength multiplexer of the drop/add type has the function of dropping and adding up to M wavelengths relative

20   to the number N of multiplexed wavelengths. Here, letter N denotes a natural number, and letter M also denotes a natural number which is

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equal to or less than the number N. In the wavelength multiplexer

shown in Fig. 1, signals demultiplexed into the respective wavelengths

of input optical signal 7 by the wavelength demultiplexing unit 3 of a

specific wavelength dropping section are derived from the specific

5   wavelength dropping section 2 (first space switching unit 1), and they

are delivered as dropped optical signals outside the apparatus. On the

other hand, optical signals to be added 13 from outside are inputted to

a specific wavelength adding section (second space switching unit 2),

from which they are delivered to an output wavelength multiplexing

10   unit 4. Such operations of the wavelength multiplexer are set as

dropping, adding and transmitting operations in each node apparatus

on the basis of the situation of settings of channels in the whole

network.

Fig. 5 is a schematic block diagram of one embodiment of the

15   node apparatus. Signals 39 of respective wavelengths demultiplexed

by an input wavelength demultiplexing unit 33 are first inputted to a

specific wavelength dropping unit 31. Subsequently, optical signals 45

of wavelengths to be outputted as dropped optical signals are derived.

On the other hand, optical signals to-be-added 44 from outside the

20   node apparatus are inputted to a specific wavelength adding unit 32,

and they are multiplexed by an output wavelength multiplexing unit

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34. A wavelength converting section 50 for wavelength conversion from input wavelengths into output wavelengths is interposed between the specific wavelength dropping unit 31 and the specific wavelength adding unit 32. Here, the wavelength converting section

5 50 has the function of converting the wavelengths of optical signals to-be-delivered in a manner to transmit the optical signals from the specific wavelength dropping unit 31 to the specific wavelength adding unit 32, without dropping or adding the optical signals. Thus, the node apparatus in the network architecture shown by way of

10 example in Fig. 4 is permitted to receive the specific input wavelength signals and to deliver the different output wavelength signals.

In the node apparatus of this embodiment, except the wavelength converting section 50, a wavelength dropping section 51 and a wavelength adding section 52 input/output signals roughly in

15 the same manner as in the foregoing node apparatus shown in Fig. 1. More specifically, the wavelength dropping section 51 includes the wavelength demultiplexing unit 33 for input wavelength-multiplexed optical signal 37, the first switching unit (or specific wavelength dropping unit) 31 and a filtering unit 35. For example, the wavelength

20 demultiplexing unit 33 and the specific wavelength dropping unit 31 are connected by an optical waveguide. The wavelength

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demultiplexing unit 33 demultiplexes the input wavelength-multiplexed optical signal 37 into optical singlans of the respective wavelengths ($\lambda 1$, $\lambda 2$, $\lambda 3$, ... and λn). The wavelength demultiplexing unit 33 suffices with a conventional one. This wavelength

5 demultiplexing unit 33 is constructed by employing, for example, a filter formed of a multilayer dielectric film, or a diffraction grating. The respective demultiplexed optical signals 39 are inputted to the specific wavelength dropping unit 31.

Optical signals 48 of the wavelengths dropped by the specific

10 wavelength dropping unit 31 are outputted from the node apparatus via the filtering unit 35. On the other hand, optical singnals 41 of the wavelengths passing through the wavelength dropping unit 31 are inputted to the wavelength converting section 50. In this wavelength converting section 50, the wavelengths which need to be converted are

15 subjected to the wavelength conversion. Desired passing lights 42 which include the lights of the converted wavelengths, are inputted to the specific wavelength adding unit 32.

The wavelength adding section 52 includes the second switching unit (or specific wavelength adding unit) 32, the wavelength

20 multiplexing unit 34 for outputting wavelength-multiplexed optical signal 38, and a filtering unit 36 for the optical signals to-be-added 44.

The optical signals 42 transmitted through the wavelength converting section 50, and optical signals 46 added via the filtering unit 36 are inputted to the specific wavelength adding unit 32. Lights 40 of the plurality of wavelengths ($\lambda 1$, $\lambda 2$, $\lambda 3$, ... and λn) outputted from the

5   specific wavelength adding unit 32 are multiplexed by the wavelength multiplexing unit 34. The wavelength-multiplexed optical signal 38 is outputted from the apparatus.

Although all the transmitted optical signals are subjected to the wavelength conversion in the embodiment of Fig. 5, only some of the

10   transmitted optical signals may well be subjected to the wavelength conversion. Thus, the node apparatus can be made smaller in size.

Here, the wavelength dropping unit or first space switching unit 31, and the wavelength adding unit or second space switching unit 32 suffice with conventional members. They are constructed of,

15   for example, optical switches etc. The construction of the wavelength converting section 50 may be any of, for example, one which uses electric signals for the conversion, and one which uses optical signals for the conversion. First, an example employing electric signals is shown in Fig. 6. The wavelength converting section 50 shown in Fig. 6

20   includes O/E conversion units 54 (O/E-1, O/E-2, ··· and O/E-N), E/O conversion (E: Electrical, O: Optical) units 56 (E/O-1, E/O-2, ··· and

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E/O-N), and electrical switching circuits 55 (55-1, 55-2, ··· and 55-N) for individual wavelengths. The electrical switching circuits 55 are interposed between the O/E conversion units 54 and the E/O conversion units 56, and they select output lines of desired wavelengths. Input optical signals 1 - N (IN-1, IN-2, ··· and IN-N) demultiplexed into the respective wavelengths by the input wavelength demultiplexing unit 33 shown in Fig. 5 are respectively converted into electric signals by the O/E conversion units (O/E-1, O/E-2, ··· and O/E-N) 54. As a result, the electric signals numbering N are obtained. Here, each of the electric signals may be handled as one signal, or it may well be deserialized into a plurality of low speed signals. All the N electric signals are inputted to each of the switching circuits 55. Then, a predetermined one of the inputted signals is selected in each of the switching circuits 55.

Here, each of the electrical switching circuits 55 is explained as having the construction of an electrical space switch. However, it can also be constructed as a time-division switch which switches the inputted electric signals in time-division fashion.

In Fig. 6, the electrical outputs of the switching circuits 1 - N are respectively inputted to the E/O signal conversion units 56 (E/O-1, E/O-2, ··· and E/O-N). The E/O signal conversion units 56 convert the

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inputted electric signals from the switching circuits 55 into optical signals (OUT-1, OUT-2, ... and OUT-N) of the respective wavelengths, and output the resulting signals toward the output wavelength multiplexing unit 34 shown in Fig. 5. The optical signals OUT-1, OUT-

5   2, ... and OUT-N correspond to the optical signals of the wavelengths $\lambda 1$, $\lambda 2$, $\lambda 3$, ... and λn, respectively. By way of example, the switching circuit 55-1 is a circuit by which any of the electrical outputs from the O/E signal conversion units 54 (O/E units) is outputted to the E/O-1 unit among the electrooptic conversion units 56. By way of example,

10   the optical signal IN-2 (wavelength $\lambda 2$) is O/E converted by the O/E-2 unit, and the resulting electric signal is outputted to the switching circuits 55. This electric signal is delivered to the E/O-1 unit among the E/O conversion units 56 by the operation of the switching circuit 1 (55-1), and the optical signal OUT-1 of the wavelength $\lambda 1$ is outputted

15   from the E/O-1 unit. That is, the optical signal IN-2 of the wavelength $\lambda 2$ is wavelength-converted into the optical signal OUT-1 of the wavelength $\lambda 1$. The other wavelengths $\lambda 2$, $\lambda 3$, ... and λn can be also converted through the switching circuits 55 in like fashion.

Next, an example in which the wavelength converting section

20   50 in the present invention is constructed of optical switches is shown in Fig. 7. In this case, optical signals delivered from the wavelength

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dropping section 51 are directly inputted to optical switching circuits 57 (57-1, 57-2, ⋯ and 57-N). Subsequently, one of the optical signals is derived by the selecting operation of each of the optical switching circuits 57, and it is outputted to the corresponding one of wavelength

5 conversion units 58 (58-1, 58-2, ⋯ and 58-N). On this occasion, the wavelength conversion units 58 convert the inputted optical signals into optical signals corresponding to wavelength Nos. 1 - N, fixedly irrespective of the wavelengths of the inputted lights. That is, the wavelengths of the lights to be outputted by the wavelength

10 conversion units 58 are respectively predetermined. Thus, the respective wavelength conversion units 58 output the optical output signals OUT-1, OUT-2, ⋯ and OUT-N of the predetermined wavelengths.

Meanwhile, a technique wherein the wavelengths of outputs

15 can be variably controlled by a single transmitting optical module has been proposed. Even with the technique, the wavelength varying function thereof can be incarnated by employing the wavelength converting section of the present invention.

There will now be described an embodiment of a wavelength

20 multiplexer in which routes for all the optical signals of "drop" signals, "add" signals and "through" signals are set by a single selection unit.

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Fig. 8 shows an example of construction in the case where signals

corresponding to all wavelengths are substituted into electric signals.

A wavelength-multiplexed optical signal 60 is demultiplexed into

individual wavelengths by an input wavelength demultiplexing unit

5   62. The resulting optical signals 63 (wavelengths $\lambda 1$, $\lambda 2$, $\lambda 3$, $\cdots$ and λN)

are converted into electric signals by an optoelectric signal conversion

unit (O/E conversion) 64 at the succeeding stage. Besides, optical

signals (adding optical signal) 69 of predetermined wavelengths to be

added from outside the wavelength multiplexer are converted into

10   electric signals by an optoelectric conversion unit (O/E conversion) 68.

Here, the electric signals of such two groups are inputted to an electric

switching circuit unit 65. In the electric switching circuit unit 65, both

routes for signals 61 to be delivered to an output wavelength

multiplexing unit 70 and for signals to be delivered (as dropped signals

15   67) outside the wavelength multiplexer can be connected at will by the

operations of space switches. The output optical signals 71 to be

delivered to the wavelength multiplexing unit 70 are optical signals

(wavelengths: $\lambda 1$, $\lambda 2$, $\lambda 3$, $\cdots$ and λN) generated in such a way that

electric signals from the electric switching circuit unit 65 are converted

20   by an electrooptic signal conversion unit 72. The optical signals

(wavelengths: $\lambda 1$, $\lambda 2$, $\lambda 3$, $\cdots$ and λN) 71 are wavelength-multiplexed by

the wavelength multiplexing unit 70, and are outputted as output light 61. The dropped signals 67 are optical signals generated in such a way that electric signals from the electric switching circuit unit 65 are converted by an electrooptic signal conversion unit 66.

5   Here in Fig. 8, how to connect desired channels is exemplified. The routes of ordinary "drop" and "add" signals are indicated as WSA (Wavelength Slot Assignment). By way of example, symbol WSA (Drop) denotes the dropping channel. Regarding this dropping channel, light of wavelength λ3 is inputted to the portion 4 of the

10   electrooptic signal conversion unit 66 by the electric switching circuit unit 65 and is converted into a desired wavelength, which is outputted as the dropped optical signal 67. The adding channel denoted by symbol WSA (Add) may be similarly considered. The optical signal to-be-added 69 inputted to the portion 2 of the optoelectric conversion

15   unit 68 is outputted to the portion 3 of the electrooptic conversion unit 72 and is converted into the optical signal of the wavelength λ3, which is delivered to the multiplexing unit 70. Discrepancy in the ratios between the numbers of "through" channels and the numbers of "drop/add" channels in individual nodes can be adjusted by making it

20   possible to set at will the number (N) of wavelengths to be inputted and the number (M) of signals to be dropped/added. Thus, the range

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of applications to node apparatuses widens.

Here, symbol WSI (Wavelength Slot Interchange) denotes a wavelength converting route. In this case, it corresponds to the installation of the wavelength converting section according to the

5   present invention to secure the wavelength converting route in a space switch. In the example of Fig. 8, input optical signal of wavelength $\lambda 1$ is converted into optical signal of wavelength $\lambda 4$, which is outputted.

Further, as shown in Fig. 8, the apparatus of this embodiment can accommodate an ordinary "through" channel (TR: Through), a

10   connection channel (HP: Hairpin) established between an "add" optical signal and a "drop" optical signal, a broadcast type channel (BC: Broadcast) in which an added optical signal is outputted as a plurality of wavelength signals, and so forth.

Optical signal to-be-added which is inputted to the portion 4 of

15   the optoelectric conversion unit 68, is delivered as dropped optical signal to the portion 2 of the electrooptic conversion unit 66 (Hairpin). Besides, optical signal to-be-added inputted to the portion 2 of the optoelectric conversion unit 68 is delivered as branched optical signal to the portions 1 ($\lambda 1$) and 3 ($\lambda 3$) of the electrooptic conversion unit 66

20   (Broadcast). Incidentally, the constituents themselves of such space switches have been known. They are introduced in, for example, Gerd

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Keiser: "Optical Fiber Communications: Second Edition" published by

McGRAW-HILL Inc., section 11. 4 PHOTONIC SWITCHING.

Network architectures in each of which a plurality of

wavelength multiplexers according to the present invention are

5   connected, are shown in Fig. 9, Fig. 10 and Fig. 11. An embodiment in

Fig. 9 is a network scheme called "linear network", in which node

apparatuses 81, 82, ⋯ and 85 are connected in one row. Besides, an

embodiment in Fig. 10 is a network scheme called "ring network", in

which node apparatuses 91, 92, ⋯ and 95 are connected in the shape of a

10   ring. Further, an embodiment in Fig. 11 is a so-called "meshed

network". The minimum network unit constructed in the linear

network or the ring network is termed a "subnetwork". In general, the

network is constituted by a plurality of subnetworks. An operation

system (OPS) 80 or 90 is connected in common in any of the networks.

15   The OPS has the man-machine interface of an administrator, and it

includes hardware such as a workstation or a personal computer,

various items of supervisory control software, and means for

communications with the node apparatuses.

Here, the administrator gives the OPS a command concerning

20   a channel which is to be actually opened. It is assumed by way of

example that a request for adding a channel from the node apparatus

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A to the node apparatus D has occurred. Then, the administrator commands the OPS to add the channel. Subsequently, wavelengths to be actually used in individual zones are selected. Regarding the selection of the wavelengths, the OPS may display the situation of uses

5   of wavelengths on the screen of a console or the like and prompt the administrator to select the wavelengths, or the OPS may well select the wavelengths autonomously under a software control. Here will be explained a method in which the OPS autonomously selects the wavelengths of the respective zones in compliance with the channel

10   setting request in the network including the multiplexers of the present invention.

In each of Figs. 9, 10 and 11, thick lines indicate the routes of main wavelength-multiplexed signals, and dotted lines indicate the routes of supervisory control signals from the OPS. The supervisory

15   control signals between the respectively adjacent node apparatuses are transferred by, for example, employing wavelengths different from those of the main signal and multiplexing them into a single fiber together with the main signal. Further, in Fig. 9, examples of operations are indicated for the respective node apparatuses 81, 82, 83

20   and 84. Besides, Fig. 12 is a flow chart for plainly elucidating examples of operations in the optical network of the present invention.

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The OPS is always supervising the situation of uses of

wavelengths in subnetworks controlled by itself. It is assumed by way

of example that a user of the channel has made a request for adding a

channel from the node apparatus A to the node apparatus D (100 in

5   Fig. 12). Upon receiving the request, the administrator of the channel,

for example, inputs a command to the effect of connecting the above

the circuit channel, from a terminal (for example, personal computer

(PC) or workstation (WS)) (101 in Fig. 12). Then, the OPS searches for

the situation of uses of wavelengths in the node apparatuses A (81), B

10   (82), C (83) and D (84) (102 in Fig. 12). In accordance with the result of

the search, the OPS determines wavelengths which are to be used

between the adjacent node apparatuses (103 in Fig. 12). Subsequently,

the OPS gives the commands of "dropping/adding certain

wavelengths" to the node apparatuses A (81) and D (84). Further, the

15   OPS gives the commands of "wavelength conversion methods" to the

node apparatuses B (82) and C (83) which are midway node

apparatuses. Concretely, the OPS transfers supervisory control signals

containing commands corresponding to the instructions, by the

communication means (104 in Fig. 12). The operations of the node

20   apparatuses responsive to the above operations are indicated in Fig. 9.

That is, each of the nodes A (81) and D (84) executes "Accepting

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wavelength dropping/adding command" (86 or 89), while each of the

nodes B (82) and C (83) executes "Accepting wavelength conversion

method instruction" (87 or 88).

Each of the node apparatuses A (81), B (82), C (83) and D (84)

5   having received the supervisory control signals judges whether or not

the transferred supervisory control signal is the instruction for its own

node, by checking a node identifier (usually termed "node ID") affixed

to the transferred signal (105 in Fig. 12). In a case where, as a result,

the supervisory control signal is the instruction for the node apparatus,

10   this node apparatus executes an internal hardware setting operation

complying with the instruction (106 in Fig. 12), and it sends an

executed result back to the OPS (107 in Fig. 12). In a case where the

node ID disagrees with that of the node apparatus, this node apparatus

relays the received control signal to the node apparatus of the

15   succeeding stage (111 in Fig. 12). More specifically, among the

instructions received by the node A (81), the instructions for the nodes

B, C and D bear the affixed node identifiers which disagree with the

node identifier of the node A itself, so that the node apparatus A (81)

relays them to the node apparatus B (82) of the succeeding stage.

20   Subsequently, among the instructions received by the node B (82), the

instructions for the nodes C and D bear the affixed node identifiers

which disagree with the node identifier of the node B itself, so that the node apparatus B (82) relays them to the node apparatus C (83) of the succeeding stage. Thereafter, similar operations are executed in the node apparatuses C and D. The above operations of the node

5   apparatuses are indicated in Fig. 9. That is, the nodes A (81), B (82) and C (83) execute "Relaying instructions for nodes B, C and D", "Relaying instructions for nodes C and D" and "Relaying instruction for node D" (86, 87 and 88), respectively. Besides, the executed result of the hardware setting operation in each node apparatus is sent back to the

10   OPS as "Sending back executed result" (86, 87, 88 or 89).

After having confirmed the normal terminations of all the node apparatuses (108 in Fig. 12), the OPS notifies the results to the operator or the administrator. Besides, the OPS updates the situation of uses of wavelengths in the subnetworks (109 in Fig. 12). Thus, the series of

15   channel opening operations are ended (110 in Fig. 12), and the ordinary service of the channel is started. Then, the OPS falls into a usual standby state.

The operations of the linear network have been explained above by way of example. However, the ring network or the meshed

20   network can also be operated in like fashion except alterations based on a different circuit arrangement.

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According to the present invention, it is possible to provide a wavelength multiplexer which can easily add new channels, and a wavelength-multiplexed transmission network which employs such wavelength multiplexers.